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THE WORLD'S GEYSER-REGIONS.

By A. C. PEALE, M. D.

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THERMAL springs, or those whose mean annual temperature exceeds that of the locality in which they are found, are almost universal in their distribution. This definition, of course, includes more than the springs usually called warm or hot, for, if the temperature exceeds, no matter in how small a degree, the mean temperature of the place in which it rises, it is truly a thermal spring. There will, of course, be a variation according to geographical position. Thus a spring which has a temperature of only a few degrees above the freezing-point would be a thermal spring in Siberia, where the ground is frozen constantly to the depth of six hundred and thirty feet, thawing out only a few feet in summer, and where the mean annual temperature is about 12½° Fahr.; whereas, in the West Indies, or in the Eastern Archipelago, it would be a cold spring. Warm and hot springs are also widely distributed. With the exception of Australia, no continent is without them, and even here they may be said to exist in a fossil state, for sinters and siliceous deposits are found in New South Wales, in a basaltic and trachytic region, indicating the former presence of hot springs, and possibly of geysers. Of course, hot springs are less widely spread than those which are simply warm, being found mainly in districts which have been affected by volcanic action, or where the rocks, from which they flow, have been subjected to disturbances such as occur in mountain elevations. Latitude, however, has no effect, for we find them equally hot in the Arctic regions and under the equator.

They are found in the frozen fields of Siberia and on the islands of Alaska, while the Andes have boiling springs from one end to the other. Venezuela and Patagonia, at the extremes of South America, both have their hot springs. When we come to geysers, we find them still more limited in their occurrence, and yet even they are confined to no particular quarter of the globe, for each continent appears to have its geyser-region. North America has the geysers of the Yellow-

stone National Park ; Asia, a geyser-region in Thibet ; while the Iceland geysers may be considered as belonging to Europe, and the New Zealand field to Australasia. Africa and South America seem to be

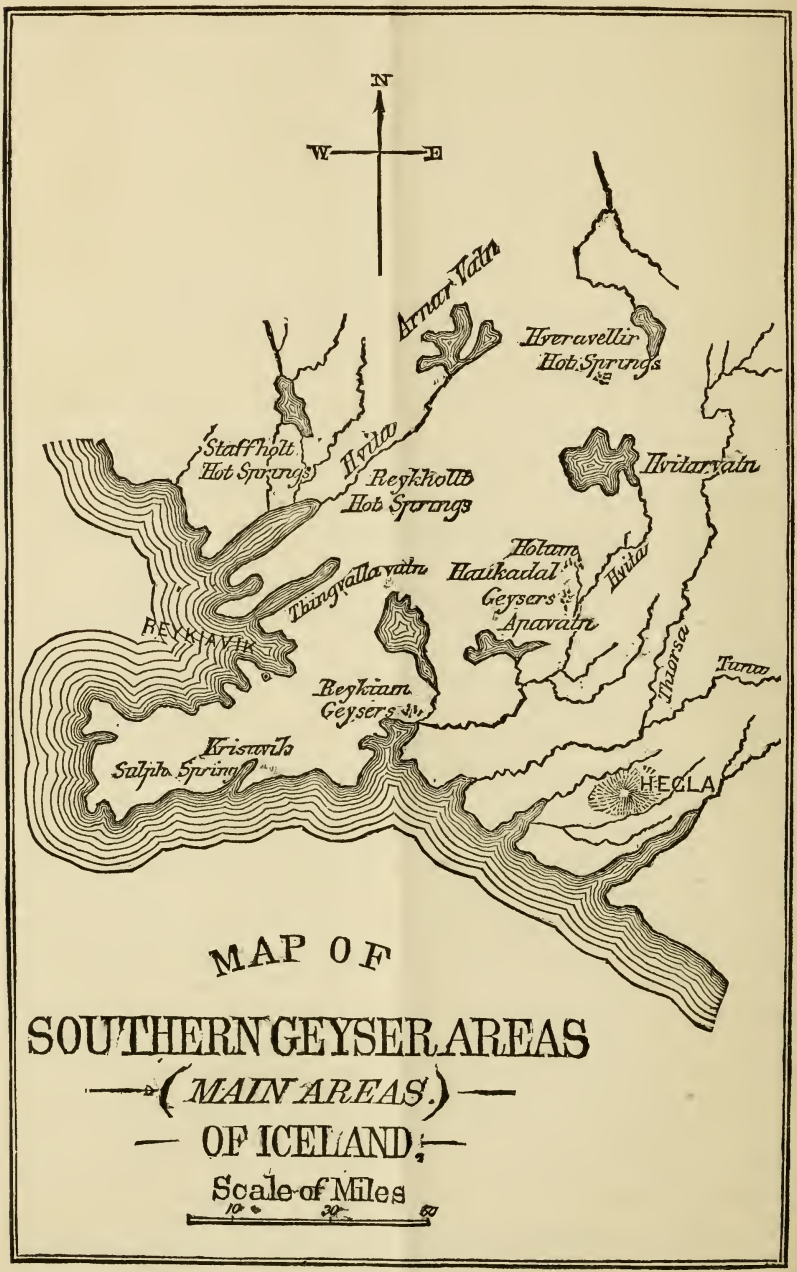

Fig. 1.

left out, and yet the comparatively unimportant geyser area of the Azores can perhaps be considered the African representative, while in the boiling lake of Dominica, and the water-volcano of Guatemala, Central and South America may be said to have geysers on a grand scale.

The difference between geysers and ordinary hot springs is not readily explained, nor always recognized, although the difference between a quiet hot spring and a geyser in active eruption is very marked. However, these are the extremes, and between the two there is every grade of action. Some geysers at times appear as quiet springs, and others are constantly in active ebullition. A geyser may be defined to be a periodically eruptive or intermittent *hot* spring, from which the water is projected into the air in a fountain-like column. The word *hot* in this definition is italicized because springs containing a large amount of gas may simulate geysers, as in the case of the Kane geyser-well in Pennsylvania, which spouts regularly, and the artesian well at Rank Herkany, in Hungary, which is fourteen hundred and fifty-seven feet deep, and spouts at regular intervals to the height of one hundred feet. Nordenskiöld discovered an intermittent cold geyser-like spring spouting through the ice-field of Greenland about thirty miles from the coast. Almost all the constantly boiling springs have periods of increased activity, and those which spout only a few feet into the air have been classed as *pseudo* geysers. There are several localities of the latter in the United States, particularly in California, and Nevada. The geysers of California belong to this class, as do also the mud-volcanoes of Southern California, although some of the latter throw columns of water to the height of twenty feet, and are true geysers. Besides the Yellowstone National Park, the Haukadal area in Iceland, and the Taupo region of New Zealand, which are the geyser-regions *par excellence* of the world, there are a number of places where a few individual geysers are known, besides the Thibet area and that of the Azores. In Mexico, at Aguas Calientes, near San Luis Potosi, there is a geyser which spouts to the height of ten or twelve feet. The Volcan de Agua, or water-volcano, of Guatemala, and the boiling lake of Dominica have already been referred to. The latter has been known since 1777. It is a seething caldron of unknown depth, measuring two hundred by more than one hundred yards, situated in the Grand Soufrière of Dominica, at an elevation of twenty-four hundred feet above sea-level. It is sometimes quiet, with a temperature of 96° Fahr., and at others is in active ebullition, with a temperature above the boiling-point, the water being thrown in jets into the air with a noise like the discharge of artillery. At Atami, in Japan, there are intermittent springs which spout about six times daily, although not with any exact regularity. An immense volume of steam and slightly sulphureted water is ejected. Geysers are found in Batachian, one of the Moluccas, and at Nolok on Celebes there is a bowl-shaped spring

seventy-five feet in diameter by twenty feet in depth that has eruptions reaching the height of fifty feet. There are other localities on the same island, and in Java also are several localities, some of which have mud-geysers that spout twenty or thirty feet. The springs of Savu-Savu on Vanua Levu, in the Feejee Islands, are *pseudo* geysers.

FIG. 2.—THE ERUPTION OF THE GEYSERS IN ICELAND, AS SEEN BY HENDERSON IN JULY, 1814.

The latter were owned by an old woman who was captured by a chief in 1863, and cooked in her own springs. Miss C. F. Gordon Cumming, referring to this, says: "She was past seventy, and must have been very tough and smoke-dried, but as in her younger days she had been a regular Joan of Arc, leading her tribe to battle, and herself

fighting hand to hand with a hatchet, he determined to eat her. So he had her cooked with the sixteen men, and made a great feast, and then to spite the people, before leaving the district, he attempted to choke up all of the springs, in which amiable effort he partially succeeded. These springs were also a favorite place for depositing all superfluous babes, especially girls, who never got much of a welcome. They were popped in alive, like so many lobsters, and treated with quite as little ceremony." Next to the Iceland geysers, which we rank below those of New Zealand and the Yellowstone Park, the most important are probably those of Thibet, although our knowledge of them is very meager. They are in Great Thibet, in the province of Chamnamring, called Chang, near Lake Namcho, or Tengri Nur, and were discovered by T. G. Montgomerie, who described them in the "Journal of the Geographical Society of London." There are six localities in the region, of which the most important are Chutang Chaka, Peting Chuja, and Naisum Chuja. At the latter, the highest temperature recorded was 183° Fahr., and the boiling-point of water was 183¾° Fahr. The first locality had fifteen hot springs, whose waters had a temperature of 166° Fahr., the boiling-point here being 186° Fahr. Peting Chuja is the principal geyser area, and a dozen columns of hot water are described as issuing from a large stony plateau and rising to a height of forty or fifty feet, producing so much steam that the sky was darkened, and so much noise that the travelers could not hear one another speaking. Similar jets were also noticed, rising to about the same height from the middle of the adjacent river, Lakú chu. The stony plateau or platform spoken of is undoubtedly a platform or mound of siliceous sinter, so common to geyser areas.

The Azores mark one of the volcanic centers of the Atlantic Ocean ridge, on which also Iceland lies. The Island of San Miguel, or St. Michael's, has hot springs in all parts, but especially in two places at the West End, in the valley of Furnas. This valley is almost circular, about twelve miles in circumference, and surrounded by volcanic mountains. Through it flows the Ribeira Quinta, or Warm River. The springs are of high temperature, and include some that spout to a height of twelve feet. They are at one end of the valley, surrounded by deposits of siliceous sinter, which forms rims eight to ten inches in height around the individual springs. The "Great Caldeira," or Boiling Fountain, is the principal geyser.

The very name, *geyser*, testifies to Iceland's historical precedence as the land of geysers. The earliest writings in relation to the island are silent in regard to them, the first mention made being by Saxo Grammaticus, who wrote in the twelfth century. Are Frode does not refer to them in the "Icelandic Annals," A. D. 1070–'75, although he lived near their present locality. If they broke forth subsequent to that period, it is surprising that not the least notice should be taken of their appearance. It must be remembered, however, that, in all but

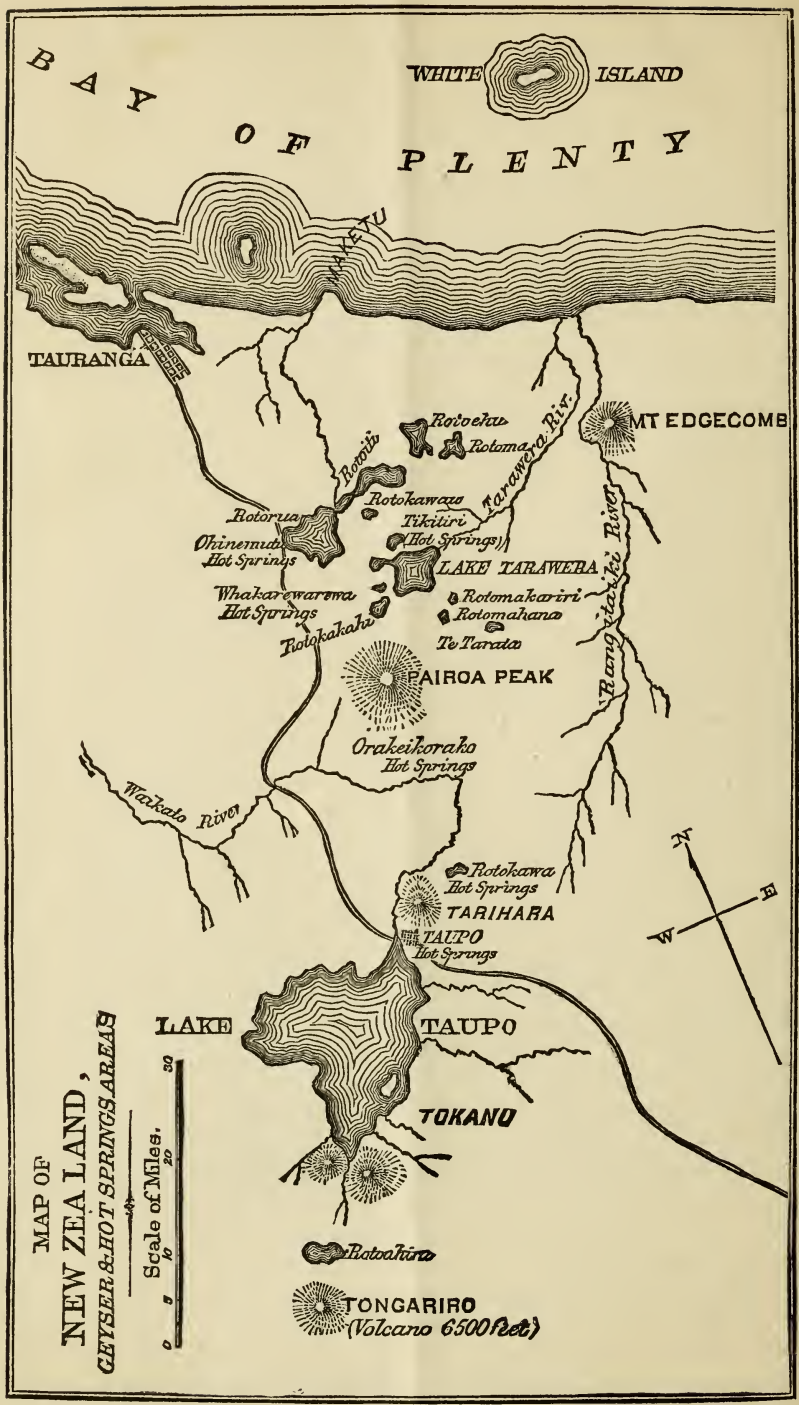
BAY OF PLENTY
WHITE ISLAND
MAKETU
TAURANGA
MT EDGECOMB
Rotoehu
Rotoma
Tarawera Riv.
Rotoiti
Rotokawau
Rotorua
Tikitiri
(Hot Springs)
Ohinemutu
Hot Springs
LAKE TARAWERA
Whakarewarewa
Hot Springs
Rotomakariri
Rotomahana
Rotokakahi
Te Tarata
Rangitaiki River
PAIROA PEAK
Orakeikorako
Hot Springs
Waikato River
Rotokawa
Hot Springs
TARIHARA
TAUPO
Hot Springs
N
E
W
LAKE TAUPO
TOKANU
Rotoahira
TONGARIRO
(Volcano 6500 feet)
MAP OF
NEW ZEALAND,
GEYSER & HOT SPRINGS AREAS
Scale of Miles.
0 5 10 20 30

FIG. 3.

highly civilized nations, physical events that do not have an immediate effect upon their worldly interests are received with indifference or apathy. Pliny, we know, gives a circumstantial account of the eruption of Vesuvius, A. D. 79, but does not mention the destruction of Herculaneum and Pompeii. It is probable that the Iceland geysers originated in prehistoric times. *Geyser*, *geysar*, *geiser*, or *geisir*, as it is variously spelled, is an old Icelandic word, meaning *gusher*, or *rager*, and is derived from the verb *geysa*, or *gjosa*, to gush, to rage, or to burst forth, to be impelled. In Iceland, in native usage, it is a proper name, being applied not only to the Great Geyser, but also to another fountain at Reykium. The word, however, has become an appellative or common name for the whole class of boiling fountains that spout hot water intermittently, just as the term *volcano* is derived from the name of one of the vents in the Lipari Islands.

The geysers of New Zealand are found on the North Island, scattered through the area which extends from Tongariro (a semi-active volcanic cone), in about the center of the island, to the Bay of Plenty. They have long been known to the natives, who have no traditions as to their age, but from time immemorial have used the quiet hot springs to warm their huts and to cook their food. Every hut has its boiler close to the door; bread is baked on large slabs of stone, placed over the hottest portions of the ground; and on others, not quite so hot, the lazy recline, wrapped in blankets, enjoying Vulcan's heat. In these respects the Maoris have the advantage over our North American Indians, who have always avoided the Yellowstone region on account of their superstitious fears.

The first white man who ever visited what is now the Yellowstone Park was undoubtedly John Colter, who was a member of Lewis and Clarke's celebrated expedition, and returned to the Upper Missouri country in 1807, and passed around Yellowstone Lake, or, as it was then called, Lake Eustis. His tales of the region were so wonderful that it was derisively called "Colter's Hell." As far back as 1844, James Bridger and Robert Meldrum, two noted Western trappers and guides, were said to have described some of the springs and geysers of the region, but their stories were so marvelous that they were not believed. The first printed description ever published was probably that given in a Mormon paper, called "The Wasp," published at Nauvoo, Illinois, in 1847. The unknown writer of this article undoubtedly visited the Lower Geyser Basin of Firehole River. Authentic information of the region was also derived from a prospecting party who visited the Lower Geyser Basin in 1863, under the leadership of Captain W. W. De Lacey. In 1869 Messrs. Cook and David E. Folsom, with another prospecting party, visited what is now the park, and the latter wrote an account of its wonders which was published in the "Western, or Lakeside Monthly," for July, 1870, where it was wrongly credited to Mr. Cook. The Washburn expedition of 1870 followed, the results

of which were published in "Scribner's" and in the "Overland Monthly," attracting universal attention. In 1871 Dr. F. V. Hayden, the 'father of the Yellowstone National Park,' made his first exploration, and published the first *scientific* account of its phenomena. Since then it has become known all over the world. Thousands of tourists have visited it, and the bibliography of the park includes a list of nearly one hundred publications in relation to it. Space here will not permit a de-

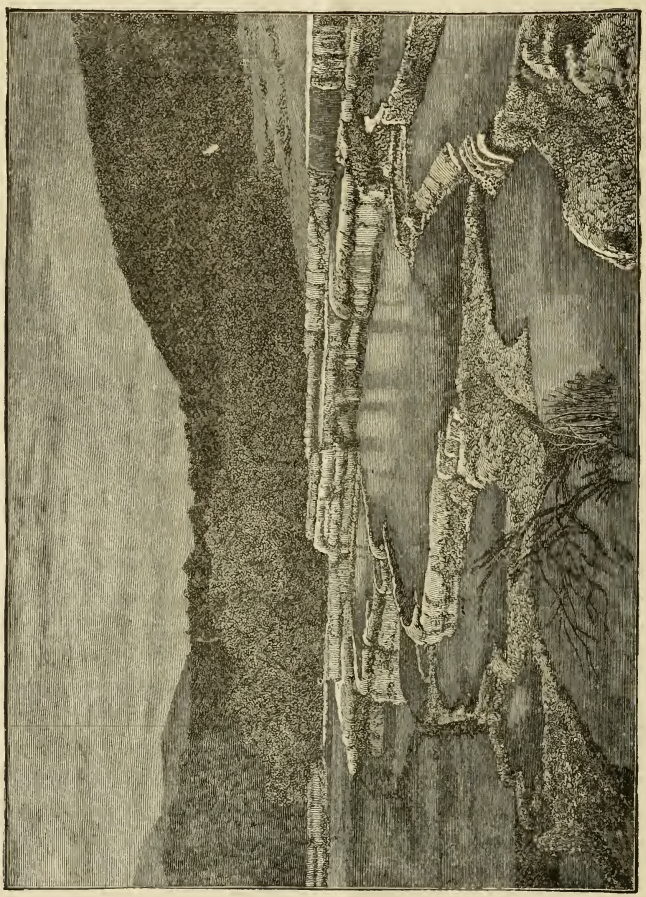

FIG. 4.—LOWER TERRACES OF TE TARATA OR WHITE TERRACE GEYSER.

tailed description of the park, nor is it necessary, but a comparison of some of its features with those of New Zealand and Iceland may be of interest. Without having seen each one of the three regions, it is, of course, difficult to make a complete comparison, and certainly it is impossible to be dogmatic. Still, Nature works according to laws that are the same in all parts of the globe, and a view of any one of the localities will, to a great extent, help to explain phenomena observed in either or both of the others. The comparison can be the more

readily made when the American locality is the one actually observed, as the others have long been known, and quite thoroughly studied and described. The maps of the three great geyser-regions present the best comparative view of them. Expressed in figures, the areas within which the springs are included are as follow :

	Square miles.
Iceland	5,000
New Zealand	2,500
Yellowstone National Park	3,578

In the southern Iceland region, which includes the Haukadal locality, there are about six areas or groups of hot springs, which are from forty to fifty miles apart. In New Zealand there are some ten groups, the greatest distance between them being about fifteen miles. In the Yellowstone National Park, there are from thirty to forty localities or groups, some quite close together, and others sixteen miles apart. In Iceland only three of the areas have geysers of note. In the Yellowstone Park eight, at least, have good spouters, and New Zealand has fully as many localities. The following table compares some of these groups. It should be premised, however, that the individual groups included under the Yellowstone Park are not a portion of the thirty or forty localities just enumerated, but subdivisions of some of them. The Upper Geyser Basin and the Lower Geyser Basin of Firehole River are really comparable with the Haukadal area, and yet the first two comprise respectively 2,560 acres and 19,200 acres.

GROUP.	Locality.	Area in acres.	Number of springs and geysers.
Geyser area of Haukadal	Iceland	20	100
Geyser area of Reykium	"	50	100
Siliceous plateau at Orakeikorako	New Zealand	1	76
Te Tarata, and east side of Rotomahama	" "	6¼	85
Castle Group Mound	Yellowstone National Park.	3½	15
Giantess Group	" " "	18	55
Grand Group	" " "	30	70
Fountain Group	" " "	15	17

In the number of springs and noted geysers, the Yellowstone National Park and New Zealand far exceed Iceland, in which "The Great Geyser" and Strokhr are the only two prominent spouters. As to the number of springs in New Zealand, there are no definite data, but they appear to be numerous. In the Yellowstone Park, over two thousand springs have been enumerated and mapped, and among them are seventy-one geysers, of which twenty are known to spout to a height of not less than fifty feet. Of course, in each of the three countries, there are hot springs outside of the areas as here indicated ; and, if these are taken into account, the American localities will exceed the others, especially if the California and Nevada springs are counted.

However, leaving the latter out of account, we find that in the adjacent country both north and south of the park there are springs on the same north and south line with the geyser-basins of Firehole River; and, if they are considered as a part of the same system, the length of the line of thermal activity is about two hundred miles.

As to the heights to which the geysers throw the columns of water, there is probably but little difference between the three regions, although the Yellowstone Park has, perhaps, a greater number which erupt regularly to a height of one hundred feet or more. The records of the New Zealand geysers are, however, somewhat deficient as to data on this point. The following table presents some comparisons as to this:

NAME OF GEYSER.	Location.	Maximum height.
		Feet.
Great Geyser	Iceland	212*
Strokr	"	162
Geyser at Reykium	"	40
Waikite, at Rotorua	New Zealand	100
Te Puia-nui, near Tokanu	" "	100†
Crow's Nest, near Tanpo	" "	50
Principal geyser at Orakeikorako	" "	30
Principal geyser on White Island	" "	100
Te Tarata, at Rotomahana	" "	50
Excelsior	Yellowstone National Park.	300
Giantess	" " "	250
Bee-Hive	" " "	219
Grand	" " "	200
Castle	" " "	200
Giant	" " "	200
Old Faithful	" " "	150
Union	" " "	114
Comet	" " "	100
Great Fountain	" " "	100
Steamboat-Vent	" " "	100
Riverside	" " "	80
Fan Geyser	" " "	75
Oblique	" " "	75
Pelican Creek mud-volcano	" " "	75
Solitary	" " "	70
Grotto Geyser	" " "	60
Fountain	" " "	50
Cliff Geyser	" " "	50‡
Surprise Geyser	" " "	30‡

This list might easily be increased, but it includes all the principal geysers. The bulk of the water in the New Zealand springs is so great that in most cases the columns during eruption do not attain great heights.

* Three hundred and sixty feet is mentioned by Olafson and Povelson, but is probably an estimate.

† A height of two hundred feet has also been recorded for one of the New Zealand geysers.

‡ These are two new geysers discovered in 1883 by Mr. Arnold Hagues, division of the United States Geological Survey.

One point which attracts attention, when the maps of these three regions are compared, is, that in each the hot springs appear to be associated with lakes. In Iceland there are six, in New Zealand fifteen, and in the Yellowstone Park four. All are of considerable size—Lake Taupo, in New Zealand, is twenty-five miles long by twenty wide; Yellowstone Lake measures twenty miles in length, by an average width of about eight miles. In Iceland, Hvitarvatn is nearly ten miles by eighteen; and Thingvallavatn has a length of about twenty miles, and a greatest width of ten or twelve miles. It is interesting in this connection to note that the Thibet geysers occur near a lake. Another point of resemblance is in the character of the deposits, which are alike in appearance, structure, and chemical composition, with the exception, perhaps, of some of the minor constituents. Silica is the predominant element in them, and is derived from the prevailing rocks. In the following table are some comparisons on these points:

LOCALITY.	Grains of silica to a gallon of water.	Percentage of silica in deposits from waters.	Character of rocks.	Percentage of silica in rocks.
Iceland	21·70 to 37·80	84·43 to 98·00	Palagonite and phonolite	41·28 72·3
New Zealand	11·48 to 43·95	77·35 to 94·20	Rhyolite and trachytes	70·0
Yellowstone Park	7·84 to 53·76	73·00 to 92·64	Obsidian and quartz-trachytes	64·60 to 77·90

The waters of New Zealand contain a much larger percentage of sodium chloride (common salt) than is found in those of the Yellowstone Park, or in the springs of Iceland.

The springs and geysers of New Zealand can be grouped in three parallel lines, and a similar linear arrangement is seen in the Yellowstone Park, and appears to be analogous to the linear arrangement so frequently noted in the case of volcanoes.

The plateau upon which the Iceland geysers is situated is surrounded on three sides with glaciers. In the Yellowstone Park, glaciers are things of the past; to-day only the erratic bowlders and scratches in the Yellowstone Valley testify to their former presence. In New Zealand the atmosphere is humid, and favorable to a growth of vegetation not found in either of the other regions. In New Zealand there are springs of greater size than those of either Iceland or the Yellowstone Park. In neither of the latter is there a hot lake like Rotomahoma, which is a mile wide by a mile and a quarter in length, and has an average temperature of 78° Fahr. The largest springs at present in the park are the Grand Prismatic spring, measuring two hundred and fifty by three hundred and fifty feet, and the small hot lake in the Lower Firehole Basin, which is one thousand feet long by seven hundred and fifty feet in width. In the past, however, the whole Lower

Basin was covered by a lake, which possibly may have been a hot lake. In our American region, siliceous cones surmounting broad sloping mounds seem to predominate. Although New Zealand has a number of cones or chimneys, the large basins are more numerous. The pool of Te Tarata measures eighty by sixty feet, and the basin of Otakapuarangi is fifty feet in diameter. The springs in Iceland are comparatively small, as a rule, and chimney-like forms are not numerous.

FIG. 5.—MAP OF YELLOWSTONE NATIONAL PARK, SHOWING THE DISTRIBUTION OF HOT SPRINGS AND GEYSERS. (Scale, ten miles to the inch.)

At Reikum the geysers have no deposits, and the "Great Geyser" at Haukadal is situated on the summit of a broad and rather gently sloping mound. Some of these differences will be rendered more apparent when placed in a tabular form:

NAME OF GEYSER.	Location.	Size at top.	Size at base.	Height of cone.
Great Geyser	Iceland	56 feet diameter	101 yards by 75 yards	12 feet.
Waikite	New Zealand		100 feet diameter	15 feet.
Crow's Nest	" "	6 feet diameter.	20 feet diameter	6 or 7 feet.
Pohutu	" "			20 feet.
Union	Yellowstone Park		18 feet circumference.	3 feet.
Flat Cone	" "	55 feet diameter		20 feet.
Steep Cone	" "	55 feet diameter		25 feet.
Bee-Hive	" "	3 feet × 4 feet.	20 feet circumference.	3 feet.
Giant	" "	8 feet diameter.	24 × 25 feet.	10 feet.
Old Faithful	" "	20 by 54 feet	145 × 215 feet.	11 feet.
Castle	" "	20 feet diameter	120 feet circumference.	12 feet.
White Dome	" "			25 feet.

The Flat and Steep cones have on their summits springs or basins of eight or nine feet diameter, and rims eight or nine inches in height. The cone of the Giant rises from a platform that is four feet high, and has a circumference of three hundred and forty-two yards. The Castle is on a platform that measures seventy-five by one hundred feet, and is three feet high, and the entire mass (platform and cone) is on the summit of a mound that is composed of deposits forty feet in thickness and covers three and a half acres.

It is difficult, and perhaps impossible, to say with certainty what the relative age of these three regions is; still, there are several reasons which seem to indicate that Iceland is the youngest and the Yellowstone Park the oldest, with New Zealand occupying the intermediate position. The first reason is based on a comparison of the volcanic condition of the three regions. Iceland is still in a state of volcanic activity. It has had eruptions as late as 1860 and 1875. There are twenty volcanoes on the island, and Hecla, which is only forty miles from the Haukadal geysers, has had twenty-two eruptions since 1004 or 1005, the date of the earliest record concerning it. In New Zealand the volcanoes adjacent to the geyser areas have sunk into the solfataric stage, and the natives have no traditions of any activity in them. In the Yellowstone National Park it is hard to say positively where the ancient volcanoes stand, although Mount Washburn has been thought to be a volcanic crater, and recently Mr. Arnold Hague has stated that Mount Sheridan may be a crater much modified by glacial action.

FIG. 6.—ERUPTION OF THE UNION GEYSER IN THE YELLOWSTONE NATIONAL PARK, AUGUST, 1878.

Secondly, when the deposits are compared, we find, as just stated, that the chimney-like form is most prominent in the Yellowstone region, while New Zealand, in that respect also, is intermediate between the park and Iceland. This more chimney-like form in the Yellowstone geysers has been explained by the statement that they contain more silica in solution, but, as already stated in the analysis already made, the percentage is usually smaller; the one exception is in a spring containing 53·76 grains of silica to the gallon of water, and it is a spring that has no conical mound. It has also been suggested that the dry air of our region may have some effect in this direction. We have no data at hand on this point; but the simpler and, to our mind, more reasonable cause is the greater age of our American region. Many of our geysers are secondary in their origin. Thus Old Faithful is a geyser that has broken out on the summit of a mound that had gradually closed up and become extinct. We can not compare the actual thicknesses of the sediments or depositions of the three regions, and, even if we could, the comparison would be apt to mislead us, as the rate of deposition in each region and among individual springs must be variable. A great antiquity, however, can certainly be accorded to all three of them. I will conclude these comparisons with a table of their elevations, including with them some of the other localities mentioned in this article:

	Elevation in feet above sea-level.
Savu Savu, in Feejee Islands	9
Hankadal geysers in Iceland	400
New Zealand geysers	1,000 to 1,300
Boiling Lake of Dominica, West Indies	2,400
Geysers of Yellowstone National Park	6,000 to 8,000
Geyser-region of Thibet	15,000 to 16,000